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SHARING CRITERIA AND PERFORMANCE STANDARDS FOR THE 11.7–12.2 GHz BAND IN REGION 2

Final Report of Working Group C (Sharing Criteria) to the Chairman of the Joint Industry/Government Committee for the Band 11.7–12.2 GHz

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Jet Propulsion Laboratory
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E. E. Reinhart, Chairman
Working Group C

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This report constitutes a consensus of the participants of the study group. Views or conclusions contained herein should not be interpreted as representing the official opinions or policies of the organizations with which the group members are associated (see Appendix B).

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I. INTRODUCTION

A. Background

The 1973 Plenipotentiary Conference of the International Telecommunication Union (ITU) resolved that a World Administrative Radio Conference (WARC) be convened for the planning of the Broadcasting-Satellite Service in the 12-GHz band (11.7-12.2 GHz in Regions 2 and 3, and 11.7-12.5 GHz in Region 1). In Region 2, this band is also allocated on a coequal basis to the Fixed, Fixed-Satellite (Space-to-Earth), Mobile (except Aeronautical Mobile), and Broadcasting Services.*

The Administrative Council of the ITU subsequently determined that the WARC would meet in Geneva in January 1977 with the following agenda:

(1) To establish the sharing criteria for the bands 11.7-12.2 GHz (in Regions 2 and 3) and 11.7-12.5 GHz (in Region 1) between the Broadcasting-Satellite Service and the other services to which these bands are allocated, namely:
- the Fixed Service
- the Mobile Service (except the Aeronautical Mobile)
- the Broadcasting Service
- the Fixed-Satellite Service (Space-to-Earth) in Region 2

(2) To plan for the Broadcasting-Satellite Service in the above-mentioned bands in accordance with Resolution No. 27 of the Plenipotentiary Conference (Torremolinos, 1973) and Resolution No. Spa 2-2 of the World Administrative Conference for Space Telecommunications, Geneva, 1971

(3) To establish procedures to govern the use of these bands by the Broadcasting-Satellite Service and by the other services mentioned in point 1 above to the extent considered necessary by the Conference

*In the U.S.A., this band is allocated on a coequal basis to the Broadcasting-Satellite and Fixed-Satellite Services, and on a secondary basis to the Mobile Service.

A Joint Industry-Government Committee was established in June 1975 to advise the Federal Communications Commission (FCC) in preparing the proposals to be set forth by the U.S.A. at the 1977 WARC concerning the use of the 12-CHz frequency band. Six working groups (WG) were appointed and designated WG-A (Definitions), WG-B (Sharing Principles), WG-C (Sharing Criteria), WG-D (Evolution of Requirements), WG-E (International Non-technical Implications), and WG-F (Procedures).

This is the report of WG-C (Sharing Criteria) and constitutes a consensus of the participants of this group.* It contains recommendations regarding the position to be taken by the United States delegation concerning agenda item 1 of the 1977 WARC.

B. Scope of the Report

The need to examine the characteristics and requirements of domestic Broadcasting- and Fixed-Satellite systems, to define sharing criteria, and to explore the possibility of adopting "performance standards" in future rules and regulations for the 11.7-12.2 GHz band is motivated by three primary considerations:

(1) Sharing criteria and performance standards to be adopted may affect the efficiency with which services in the 11.7-12.2 GHz band can share the orbital arc and the frequency band.

(2) As previously noted, the 11.7-12.2 GHz band is allocated to two space services and three terrestrial services in Region 2. Without appropriate sharing criteria and performance standards, it is possible that certain applications within these services may be precluded. Moreover, the sharing criteria and performance standards may affect the quantity and quality of communications that can be achieved in certain applications.

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*The membership list for WG-C is given in Appendix B.

(3) Fixed-Satellite and Broadcasting-Satellite systems operating in the 11.7-12.2 GHz band may affect or be affected by: (a) U.S. terrestrial services in the band on a secondary basis, (b) both satellite and terrestrial systems that may be implemented outside of the U.S. in the 11.7-12.2 GHz band, and (c) satellite and terrestrial services that operate in the bands adjacent, or in harmonic relation, to the 11.7-12.2 GHz band.

A United States position relating to new radio regulations for the operation of Fixed-Satellite and Broadcasting-Satellite Services in the 11.7-12.2 GHz band must be predicated upon detailed analyses of the technical performance of systems in these services. This must include an assessment of the intersystem interference potential of the two satellite services, and the interference potential of these satellite services to and from terrestrial services operating within the band and adjacent to it.

At this time, the technical characteristics of domestic satellite systems that will operate in this band are not well defined. This is particularly true of the Broadcasting-Satellite Service in Region 2. In addition, the interpretation of the definitions of Fixed-Satellite and Broadcasting-Satellite Services is currently evolving.

In view of the foregoing factors, this report is limited primarily to an identification and discussion of the technical considerations that determine the suitability of various system and subsystem parameters as candidates for specification as sharing criteria or performance standards. Specific recommendations are given in the case of a few parameters, but it is believed that the specification of additional criteria and standards should await further definition of the services that will share the band and more authoritative information on the technical characteristics and economic considerations of systems in those services.

II. SHARING CRITERIA AND PERFORMANCE STANDARDS FOR SATELLITE SYSTEMS SHARING IN REGION 2

A number of system parameters have been suggested as candidates for sharing criteria and performance standards in the responses to Notices of Inquiry in FCC Docket No. 20468, in technical papers, in International Radio Consultative Committee (CCIR) reports and documents, and as a result of the Joint Industry/Government Committee meetings. Candidate parameters can be classified into three categories:

(1) System Parameters

(2) Space Station Parameters

(3) Earth Station Parameters

Table 1 presents a listing of the candidate sharing criteria and performance standards under the three categories defined above.

TABLE 1

CANDIDATE AREAS FOR SHARING CRITERIA

System	Space Station	Earth Station
Polarization	Stationkeeping	Receiver interference rejection
Channelization	Satellite repositioning	Antenna size and discrimination
Quality of communications	Out-of-band emission limits	Receiver noise temperature
Energy dispersal	Cessation of emissions	Antenna repointing and receiver retuning
Modulation methods	Power flux density limits	Antenna pointing accuracy
Acceptable levels of interference	Antenna pointing accuracy	

A. System Parameters

1. Polarization. The use of orthogonal polarization can increase the capacity of the geostationary orbit reaching, in the limit, twice the capacity that could be realized with a single polarization. For example, satellites can be spaced more closely, with orthogonal polarization used on cochannel signals from adjacent satellites. Alternatively, it may be practical to use both polarizations within a single channel (or on frequency-interleaved channels) from the same satellite if the isolation required to avoid interchannel interference is not too great.

For the first years of service in the 11.7-12.2 GHz band, the capability to place satellites closer together appears to offer advantages over frequency reuse in a single satellite. However, in the special case where adjacent satellites have identical interleaved channelization plans, the benefits of both adjacent satellite cross polarization and adjacent channel cross polarization may be obtained. That is, by alternating between orthogonal polarizations on a channel-by-channel basis in each satellite and having orthogonal polarizations between similar channels in the adjacent satellite, both types of polarization discrimination can be achieved.

Orthogonal polarization can be obtained in the case of linearly polarized signals by the use of horizontal and vertical polarization; or, in the case of circularly polarized signals, by the use of right- and left-hand senses of polarization. Linear polarization is generally preferred because it affords greater discrimination in the sidelobes. However, there are some operational advantages in the Broadcasting-Satellite Service in the use of circular polarization (i.e., earth station antennas need not be aligned).

Several factors influence the amount of overall polarization discrimination that can be obtained in practice: the discrimination in different parts of the antenna beam, the frequency of operation, polarizer performance, the depolarization due to atmospheric and ionospheric effects, scattering from the ground, satellite orientation stability, intersystem geometry, and polarization tracking.

Although upwards of 33 dB of discrimination can be obtained within the 1-dB gain contour of a large-aperture antenna, the other factors mentioned above combine to reduce the overall discrimination to less than 25 dB in the main beam for a 4- and 6-GHz band signal subject to the influence of the atmosphere and the ionosphere. In the sidelobes of the antenna beams, the overall cross polarization discrimination at 4 and 6 GHz may be less than 10 dB.

The amount of polarization discrimination that can be achieved and maintained over long periods in systems operating at 12 GHz or above is not accurately known. While the depolarizing effects of Faraday rotation decrease with increasing frequency, the depolarization of signals due to precipitation increases markedly as the frequency is increased. In the presence of rain, the polarization discrimination that can be relied on in the 12-GHz band in the main beam may be quite small, and may be even less in the sidelobe region. However, at the same time that depolarization is taking place, signal attenuations are usually high due to absorption and scattering by precipitation to the point where the link may be out of service anyway.

Because of the improvements in utilization of spectrum and orbit that can result, it will be desirable to incorporate some form of polarization discrimination into the design of future systems. Because of the lack of definitive information, it is considered premature to recommend a specific polarization plan as a standard. In the interim, system designers are urged to use polarization discrimination in their design considerations. We expect that results of the Canadian Technology Satellite (CTS) experiments will provide useful information in this area.

2. Channelization. Channelization pertains to frequency usage or a frequency plan that sets forth: (a) location of carrier frequencies, (b) assignment of bandwidth to usable communications, and (c) assignment of bandwidth to guard bands. Good practice in the channelization of the 500-MHz bandwidth included in the 11.7-12.2 GHz band should involve a high-percentage allocation of bandwidth to usable communications while allowing for adequate protection for both in-band and adjacent band services.

Frequency interleaving, or the technique of offsetting the carrier frequencies of one satellite (or one set of transponders in a single satellite) relative to the carrier frequencies of another can reduce the likelihood and level of interference, and thus increase the efficiency of orbit and spectrum utilization.

Because of both the wide diversity in services that have been hypothesized and which could be offered in this band, and the resulting large differences in the characteristic bandwidths of systems designed to supply these services, it is premature to recommend any specific channelization plan as a standard or to specify a minimum allocation of the 500 MHz to usable communications. This wide diversity is evident from a review of the possible systems set forth in the U.S. CCIR contribution (Doc. USSG BC/838) entitled "Functional User Requirements." However, system designers are urged to develop frequency plans that make efficient use of the frequency band for usable communications.

With regard to the protection of out-of-band services, the objective is to establish an acceptable level of interference (see Section B3). The system designer should then have the freedom to select among the use of guard bands, filtering, satellite location, effective isotropically radiated power (EIRP), antenna pattern, etc., to meet the interference objective.

3. Quality of Communications. CCIR Recommendation 289 sets forth minimum signal-to-noise (S/N) ratios which should be achieved in a "2500-km hypothetical reference circuit for the transmission of television." These values range between 50 and 57 dB, depending on the kind of system, for the peak-to-peak luminance signal to r.m.s. weighted noise. Such high ratios are desirable because such television signals often will be distributed further over large distances and will suffer some subsequent impairments before they reach the viewer.

In the case of Broadcasting-Satellite systems, however, the receiving installations will be much closer to the viewer, and will not be significantly degraded further by subsequent transmission systems. Thus, lower design

values for signal-to-noise ratio should be sufficient. For instance, CCIR Report 215-3 gives examples of 12-GHz Broadcasting-Satellite systems for community and individual reception as having S/N ratios of only 42 dB. These lower required signal-to-noise ratios permit either lower EIRP or lower earth station gain-to-noise-temperature ratios (G/Ts) or both. They also allow higher levels of intersystem interference, and hence closer satellite spacings than would be required in higher-S/N systems.

In the case of Fixed-Satellite systems, the noise power in a telephone channel of a satellite-supplied "hypothetical reference circuit for frequency division multiplex (FDM) telephony" should be as set forth in CCIR Recommendation 353-2. For example, the total noise from all sources should not exceed 10,000 pWop more than 20 percent of the time. Although no reduction in these levels for the quality of channels to remote areas which do not require further distribution by landline is discussed in the recommendation, recently proposed systems have been designed using lower S/N levels.

It is important to set a limit not only on the minimum quality to be supplied but on the maximum quality that should receive protection from interfering sources. High-quality systems impose a requirement for low levels of interference from other systems sharing the orbit and the spectrum. No recommendation can be made at this time of this upper level to be protected until further studies have been made.

4. Energy Dispersal. During certain transmission periods, the peak power density of a carrier may significantly increase (during times of low traffic on multichannel telephone circuits, or the transmission of an all-black or all-white television scene). During such transmission periods, the peak power density can be reduced, thereby limiting the peak interference presented to other sharing services by causing the carrier energy to be dispersed. As discussed in CCIR Report 384*, the use of currently available energy dispersal techniques can reduce the peak power density, per 4 kHz, during light loading to within 5 dB of that during full loading conditions.

*Texts of the XIII Plenary Assembly of the CCIR, Volume 4, Geneva, 1974.

While it would be desirable to require the carrier energy to be dispersed during these times to limit the peak interference presented to other sharing services to an acceptable level, there could be a significant impact on the cost of Broadcasting-Satellite systems. Energy dispersal could require modification to the television set or abandonment of inexpensive receiver/converter units which transform broadcasting satellite frequency modulation (FM) into standard TV amplitude modulation (AM).

With these considerations in mind, we recommend the establishment of an acceptable level of interference or a peak power flux density as the more basic sharing criteria, thus leaving to the system designer the methods of achievement, which include, among other things, the use of energy dispersal techniques.

5. Modulation Methods. To keep spacecraft power requirements to practical levels, either frequency modulation or phase-shift-keying (PSK) is normally preferred for both Fixed-Satellite and Broadcasting-Satellite systems. For a given baseband, however, the RF bandwidth occupied by the modulated carrier depends on the peak-to-peak deviation (for FM) or the number of transmitted phases (for PSK) specified by the system designer. His choice depends, in turn, on the desired signal quality within the constraints of available satellite EIRP, bandwidth, and expected channel noise. In addition, economic considerations and multiplexing and signal processing techniques used in forming the baseband are important.

Although orbit-spectrum utilization tends to increase as the ratio of RF bandwidth to baseband bandwidth increases, economic considerations may favor modulation parameter values that require less RF bandwidth in preference to those that minimize RF power requirements or maximize orbit-spectrum utilization. For these reasons, coupled with uncertainties in system requirements and characteristics and evolving technology, it is premature to specify system standards regarding modulation methods or RF channel bandwidths. Further, it may never be desirable to specify modulation standards since other more basic criteria may influence system design to produce efficient and shared use of the orbit and spectrum.

6. Acceptable Levels of Interference. The definition of acceptable levels of interference is a fundamental sharing criterion because the required spacing between adjacent satellites operating in the 11.7-12.2 GHz band is directly related. Traditionally, the level of interference from a satellite into a terrestrial earth station is limited to 1000 pWop.* (This amounts to 10 percent of the total system noise budget of 10,000 pWop.) For the case of interference from satellites into earth stations of other satellite systems, a limit of 1000 pWop is also recommended.**

However, orbit-spectrum utilization usually can be improved without sacrificing message quality by permitting a higher interference level in combination with a compensatory reduction in the permitted thermal and intermodulation levels. To illustrate, changes from the values presently employed in the proportion between interference and thermal noise may lead to an overall improvement in the utilization of the band. Further study is necessary in this area, especially for thin-route applications.

Acceptable levels of interference for the 11.7-12.2 GHz band may differ from those established for the 4- and 6-GHz band. Definition of these new levels will require an understanding of the specific types of new services that may be offered by Broadcasting-Satellite and Fixed-Satellite systems that will share the band. Because of the general uncertainties that presently exist in such service definitions, studies should be directed toward amending current CCIR recommendations as may be appropriate (e.g., for transmission of digital voice), and developing new recommendations to address special and new services that may be offered (e.g., transmission of wideband digital signals).

B. Space Station Parameters

1. Stationkeeping. East-West excursions of the satellite will increase the spacing required between adjacent satellites to keep interference to an acceptable level. In turn, the degree to which the orbital arc and the 11.7-12.2 GHz band are efficiently utilized is affected.

*CCIR Recommendation 357-2 (Texts of the XIII Plenary Assembly of the CCIR, Volume 9, Geneva, 1974).

**CCIR Recommendation 466 (Texts of the XIII Plenary Assembly of the CCIR, Volume 9, Geneva, 1974).

Considering the negligible amount of fuel needed to control East-West excursions of a geostationary communications satellite and the desire to maximize the number of satellites which may share the orbital arc, a requirement to maintain each satellite to within ±0.1 degree appears reasonable and is recommended. North-South stationkeeping may also be appropriate to preclude the requirement for earth station antenna tracking, to reduce the loss due to pointing error, or to minimize the energy radiated outside the desired coverage area.

To be more specific, the amount of satellite motion allowed involves several considerations which affect sharing. First, the drift in the East-West direction is essentially wasted orbital space. That is, satellite spacing will be primarily determined by an allowable level of interference presented to the earth stations operating with adjacent satellites. The allowable satellite drift must be added to the minimum separation based on interference considerations. To illustrate, if satellite drift is tolerated to ±1 degree, 2 degrees of wasted orbital arc result per satellite. For satellites operating in the Fixed-Satellite Service, ±1 degree drift will require the earth station antennas to track the satellite to keep it in the main beam. For smaller earth station antennas, large satellite excursions will impose large pointing losses or the requirement for a tracking antenna. The last point to be considered is that the weight penalty is generally insignificant for East-West control. With these considerations in mind, it is concluded that satellites should be controlled to at least ±0.1 degree.

With regard to North-South control, although some of the same considerations apply, the impact on satellite spacing and interference to earth stations operating with adjacent satellites is considerably smaller. Satellites in near-geostationary orbit will drift in inclination approximately 0.8 degree per year, giving rise to motion which is primarily in the North-South direction. Pointing loss which results from this inclination can be compensated for by increasing satellite EIRP or, to a certain extent, by spacecraft antenna repointing. Increasing EIRP is generally an undesirable solution since it increases the likelihood of interference and is wasteful of spacecraft power

and weight. It is our recommendation that North-South stationkeeping limits not be specified. Rather, we recommend that the system designer offset the effects of North-South motion either through stationkeeping to ±0.1 degree or through the combination of earth station antenna design and space station antenna pointing to keep the satellite radiated power level and footprint the same as it would be with the satellite North-South motion controlled to 0.1 degree.

2. Satellite Repositioning. Requiring satellites to have the capability to be repositioned will increase the flexibility of Administrations in assigning orbital positions as they are applied for without precluding the implementation of an orbit-sharing plan in the future. Considering cost (fuel)*, it appears reasonable to require limited move capability after the satellite has been established in an assigned position. A total excursion of approximately 10 degrees might be a reasonable bound consistent with maintaining system performance and requiring, at most, repointing at the satellite antenna. The performance impact is a function of the initial station, the desired coverage area, and the degree of antenna pattern shaping employed in optimizing antenna gain and reducing spillover. Larger excursions can require a broadening of the antenna pattern (loss of gain in spillover) to accommodate the altering shaping of the coverage area from different satellite view angles corresponding to the shift in the satellite longitude. On-orbit shaping of the antenna coverage pattern is impractical with satellite antennas of the type used today and must await the development of practical phased array (or equivalent) antennas.

In the future, two changes may evolve which will alter the position established here. First, antenna configurations and patterns may become more complex, leading to more sensitivity to satellite position and therefore reducing the allowable amount of excursion before requiring realignment.

*With current designs, the expenditure at approximately 1 percent of total on-orbit satellite weight for repositioning fuel will make possible one reposition at 3 degrees/day. Alternatively, this same amount of fuel can be used for more repositions at slower rates. A single reposition of 10 degrees/day would increase the fuel requirement by a factor of approximately three. No recommendation is made here for the percentage of satellite weight to be allocated for repositioning fuel.

The second change may be advancements in the state-of-the-art related to the capability to remotely realign the satellite antenna pattern from the ground. The final point to be made is that a satellite repositioning will affect the earth stations and must be considered as discussed in Section C4.

3. Out-of-Band Emission Limits. At present, the ITU Radio Regulations do not specify tolerable levels of spurious emissions (either in- or out-of-band) above 235 MHz, stating only that they should be "as low as practicable." Receivers with inadequate frequency selectivity will be subject to interference from out-of-band transmissions, and transmitters having insufficient suppression of spurious emissions will cause such interference. Theoretically, no transmitter can be perfectly "clean" nor receiver completely immune even at frequencies far removed from the desired channel, but in practice the problem is of concern mainly in the adjacent frequency channels and at band edges, especially where the characteristics of the systems change markedly from one service to another in the adjoining band (as in the case of radio astronomy at 2690 MHz, which is adjacent to the 2500-2690 MHz Broadcasting Satellite band). Interference can be reduced by both decreasing the level of out-of-band emissions and reducing the out-of-band sensitivity of receivers. The burden of minimizing interference should fall on both services.

In the case of interference to the Fixed and Mobile Service in the band 10.7-11.7 GHz from satellite emission in the band 11.7-12.2 GHz, one measure of degradation is the out-of-band interference as a percentage of the total permissible in-band interference. Values between 1 percent and 100 percent have been suggested (that is, levels between 20 and 0 dB, respectively, below the aggregate of currently permissible interference from in-band satellite systems).

A preliminary and simplified analysis is outlined in Appendix A for the case of permitted interference of 10 dB below in-band satellite interference, which leads to an estimate of the order-of-magnitude of the interference problem that may be created by satellites operating in the 11.7-12.2 GHz band to services operating in the band immediately below 11.7 GHz. Five types of satellite systems are considered:

Type 1	Fixed-Service	Wideband Digital
Type 2	Fixed-Service	Narrowband Digital
Type 3	Fixed-Service	Second Generation
Type 4	Broadcasting-Service	EIRP = 55 dBw
Type 5	Broadcasting-Service	EIRP = 65 dBw

Radio Regulation 470NQ now specifies power flux densities (PFDs) that satellite systems may generate, based on a calculation of the in-band interference that would likely result. It should be pointed out that the PFD limit adopted by the ITU in Radio Regulation 470NQ for the 10.7-11.7 GHz band was not the result of a definitive study of the effect of a model array of satellite interferers on typical radio-relay systems. Rather, the PFD limit previously established at 4 GHz (470NL) was extrapolated to higher frequencies, taking some — but not all — of the systems differences into account. Moreover, additional study is required on the manner in which out-of-band emissions add to the level of interference as well as affecting system availability. Therefore, no recommendation can be made at this time.

Calculations should be made of the interference caused to terrestrial systems in the 10.7-11.7 GHz band by an assumed array of Broadcasting Satellites and Fixed Satellites in the 11.7-12.2 GHz band, taking into account that regional allocations differ.

Transmission of terrestrial services in bands adjacent to the 11.7-12.2 GHz band should be analyzed to determine the levels of interference that would be caused to Broadcasting-Satellite and Fixed-Satellite systems in the 11.7-12.2 GHz band, including the susceptability of earth stations to adjacent band emissions.

4. Cessation of Emissions. Capability to command service emissions to be turned off if the satellite deviates beyond standards prescribed for sharing compatibility is recommended. This capability is suggested to avoid interference with sharing services when the satellite deviates beyond the limits established for excursions from its assigned location or deviations from authorized operating characteristics.

5. <u>Power Flux Density Limits</u>. The issue of power flux density limits raises a number of difficult questions; for example:

(1) Should a limit be established?

(2) If so, how should the limit be established and when should it be imposed?

(3) Should power flux density limits be different for different services sharing the same band?

(4) If so, on what basis should the limits be different?

(5) How are satellites offering both Fixed and Broadcasting Services dealt with?

(6) What are Fixed and Broadcasting Services?

(7) Should a limit be established outside the service area? Should it have a different value?

Power flux density limits are generally addressed from two points of view: first, the impact of PFD on orbital spacing requirements and second, what PFD is needed for a particular application. Clearly, in the limit, as the allowable EIRP is increased, the number of satellites which may share an orbit segment approaches unity. This consideration leads to two general conclusions. First, if an application is put forth whose implementation requires an extremely high EIRP, it is questionable whether the system should be approved even if the need based on the application for the high EIRP can be established. That is, acceptable levels of EIRP must be determined from both "need" considerations and their impact on other services sharing the band. The second conclusion to be drawn is that at some time PFD limits must be established if a proposed service would require an EIRP level which would cause excessive interference if not the exclusion of other services in the band.

The question of different limits for different services in the band is a most difficult one from several points of view. It has already been stated that justification of a PFD must go beyond the simple establishment of a "need." A second point of view concerns the lack of agreement which now exists as to what a Fixed-Satellite or a Broadcasting-Satellite Service is. A third point concerns the possibility that both Fixed and Broadcasting

Services may be offered by the same satellite or through the same satellite transponder channel.

In summary, the need for a power flux density limit at some time is likely. The timing for such a limit is not known.

6. Antenna Pointing Accuracy. The accuracy with which a satellite antenna beam is pointed affects the (1) signal level within the desired coverage area, (2) interference levels in adjacent areas, and (3) interference at the satellite via the uplink. Considering (1), the design is generally such that a given signal quality is provided at the edge of the coverage area. To achieve this requires the proper combination of satellite EIRP, beam pointing accuracy, and earth station G/T. The tradeoff and subsequent selection of the parameters is a system design function.

While the determination of (1) should be the prerogative of the designer, it may be desirable to constrain his choice of antenna beam pointing accuracy since this directly impacts orbit/spectrum utilization, as indicated by (2) and (3). Further, a relatively tight control is implied since the gain slope of the antenna is quite high at the edge of the coverage area; hence a small angular error can significantly affect mutual sharing capability. On the other hand, increasing pointing accuracy implies increasing spacecraft cost and complexity. For example, it may be necessary to improve attitude control techniques and/or include pointing aids such as interferometer tracking.

The manner and degree to which beam pointing should be controlled, if at all, is not straightforward; hence any recommendations should be the result of a study considering at least the following:

(1) Impact on spacecraft complexity and cost
(2) Impact on spectrum/orbit utilization
(3) Tradeoff between specifying constant pointing error and/or pointing error as a function of beamwidth
(4) Recommended sidelobe patterns as presently undergoing review of WARC 77.

C. Earth Station Parameters

1. Receiver Interference Rejection. The question of receiver interference rejection capability was introduced in general terms in the section on out-of-band emission limits (Section B3).

Filtering in the satellite is difficult in terms of the weight and volume it requires and the insertion loss it causes, but the same requirements may not be as costly or difficult to achieve in earth stations — even those designed to be low-cost. Current low-cost receiver designs at 12 GHz are capable of 30-dB rejection at the center frequency of an adjacent channel 40 MHz away.

Even so, interference rejection does not appear to be a characteristic that should be regulated. Rather, a limit should be set on the out-of-band interference reaching an earth station. The system designer must then design his system to provide the desired service quality in the presence of such interference.

The level should follow the equal burden principle previously set forth. That is, the interference reaching earth station receivers operating in the 11.7-12.2 GHz band from out-of-band emissions should be as small as any limits established to protect out-of-band receivers from 11.7-12.2 GHz band emissions (see Section B3).

2. Antenna Size and Discrimination. Orbit/spectrum utilization can be increased by employing narrow earth station antenna patterns (beamwidths) having low sidelobe levels. This worthwhile goal implies larger-aperture and more costly antennas. Such capability is inherent in most Fixed-Satellite Service earth stations since economic considerations dictate such an approach when there are a relatively small number of earth stations involved. As the demand for satellite service increases, it becomes desirable to decrease the cost of the earth station equipment since this tends to promote the growth of the service. This could imply smaller, less costly antennas, suggesting that benefits of a service, as well as orbit/spectrum utilization, should be

considered when imposing standards. In view of this, and the preliminary nature of the satellite services in this band, it is believed that constraining antenna size would be premature. On the other hand, reasonable sidelobe control should be implemented, and recommendations are now under study.

3. Receiver Noise Temperature. Low receiver noise temperature implies that lower EIRP satellite transmissions may be employed to achieve a required level of system performance. For a given level of total satellite power, the lower the earth station receiver noise temperature, the higher the capacity of the satellite and therefore the higher the efficiency in the use of the orbital slot and the spectrum.

The designer's choice, in his selection of the earth station receiver noise temperature, is influenced by two primary considerations — one technical and one economic. From a technical viewpoint, as the receiver noise temperature is reduced to increase the capacity of the system, the receiver becomes more susceptible to the effects of rain and to interference from adjacent satellite transmissions. From an economic viewpoint, the earth station cost increases with decreasing receiver noise temperature.

Since the efficient use of the orbital arc and the spectrum is of fundamental importance in our considerations in this report, the use of low-noise receivers is to be encouraged. However, several attendant factors must be considered. Low-noise receivers will require increased protection from adjacent satellite interference and higher elevation angles to the satellite to limit the effects of rain. On the other hand, low-noise receivers lead to lower satellite radiated power and therefore less interference to other systems.

Conversely, the use of inexpensive receivers leads to higher noise temperature. This in turn requires a higher level of satellite EIRP per channel, thus resulting in smaller channel capacity and higher levels of interference to other systems.

In summary, the use of low-noise receivers allows greater utilization of the orbital arc and reduced spacing requirements based on interference presented to adjacent systems. However, systems employing low-noise receivers will have to be protected from other systems using considerably higher levels of satellite radiated power. In addition, low-noise-temperature systems will require use of those segments of the orbital arc which allow high pointing angles to the satellite to limit the increase in system noise temperature due to rain.

No recommended standards for receiver noise temperature per se are proposed since efficient use of the orbit and spectrum can be achieved by the establishment of other standards. For example, maximum permissible interference power flux density will achieve the same result while giving the system designer the desired level of flexibility in his selection of system parameters and components.

4. Antenna Repointing and Receiver Retuning. The ability to reposition a satellite and/or reassign channel frequencies would increase the flexibility of Administrations to make efficient orbital/frequency assignments as new satellites are added in the future. This implies the need to repoint the earth station antenna and retune the receiver* over the 11.7-12.2 GHz band.

The impact of such requirements on earth stations in the Broadcasting-Satellite Service and even on some Fixed-Satellite systems may be significant. For systems with many earth stations, a small increase in unit cost could result in a large increase in total system cost. Also, the adjustment of earth station equipment could be complicated. It is recognized that a satellite reposition will require an earth station repointing capability; in view of the complications enumerated above and the service outage that will occur, the number of satellite repositions should be minimized. For many of the same reasons, the number of times an earth station must retune should also be kept to a minimum.

*The transmitter would also have to be retuned, but this aspect is not discussed here since such uplinks are not in the 12-GHz band or even in the Broadcasting-Satellite Service.

5. <u>Antenna Pointing Accuracy</u>. The accuracy with which an earth station beam is pointed affects the (1) signal level from the desired satellite, (2) interference levels at adjacent satellites, and (3) interference at the terminal via undesired satellite downlinks. However, we do not recommend a performance standard for this area. Rather, the satellite EIRP and spacing between adjacent satellites should be specified at values based on "good" earth station antenna pointing practice and not increased to make up for the lack of pointing accuracy. Further study is required to define "good" antenna pointing practice.

III. SHARING CRITERIA CONSIDERING SATELLITE SYSTEM SHARING WITH TERRESTRIAL SERVICES

In Section II, sharing criteria and performance standards were discussed considering orbital sharing in Region 2 between the Fixed-Satellite (F-S) Service and the Broadcasting-Satellite (B-S) Service. This section considers other sharing situations, particularly as they affect or are affected by the two satellite services in Region 2. The situations include:

(1)	Fixed and Mobile	Broadcasting-Satellite
(2)	Broadcasting-Satellite	Fixed and Mobile
(3)	Fixed-Satellite	Fixed and Mobile
(4)	Broadcasting-Satellite	Broadcasting
(5)	Broadcasting	Broadcasting-Satellite
(6)	Fixed-Satellite	Broadcasting
(7)	Broadcasting	Fixed-Satellite

A. Sharing Between Satellite and Fixed and Mobile Services

The interference paths to be considered here will be those between the Fixed and Mobile (F&M) Services on one hand and both the Broadcasting-Satellite and Fixed-Satellite Services on the other. Table 2 indicates the possible interference paths. It also describes the present Radio Regulations, if any, controlling interference on those paths. Lastly, it sets forth, in general terms, the controls or techniques or Regulations that should be adopted to permit use of the band either on a primary or secondary sharing basis.

Column 1 of Table 2 treats interference from the Fixed and Mobile Services to the Broadcasting-Satellite Service.

The interference path at 11.7-12.2 GHz is from F&M transmitters to earth stations receiving from B-S. A circle in this column indicates that some new Radio Regulation is needed. The interference paths will not cause

TABLE 2

INTERFERENCE PATHS

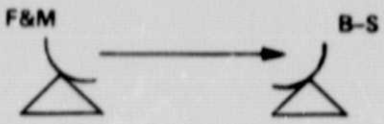
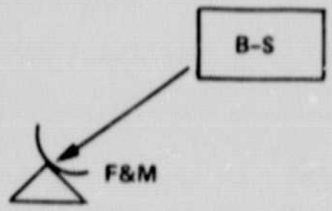
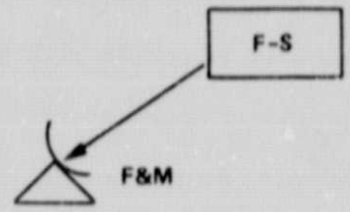
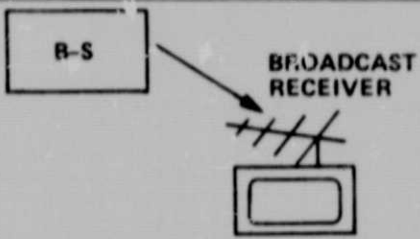
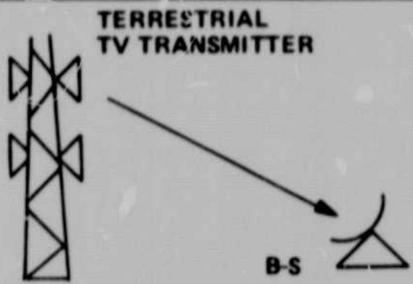
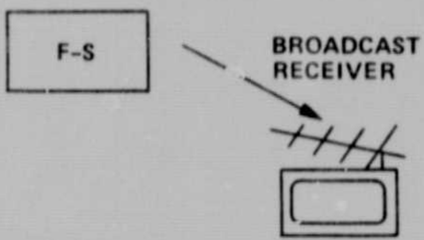
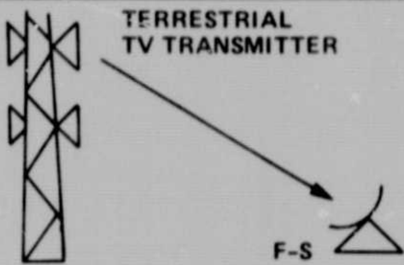
1. F&M → B-S	2. B-S → F&M	3. F-S → F&M
		
Path: From F&M transmitters to earth station receivers of B-S 1. No change needed In U.S. and Canada. 2. Make secondary in region or only in Mexico. 3. Establish PFD at the border (see Figure 2).	Path: From B-S transmitters to F&M receivers In U.S. and Canada, F&M are secondary: no PFD or other change needed. For other countries in Region 2 and for Regions 1 and 3, a limit would have to be adopted for PFD in those areas.	Path: From F-S transmitters to F&M receivers Now controlled by PFD limits in bands other than 12 GHz (RR 470N-470Nz). In U.S. and Canada F&M are secondary: no change necessary. In other countries in Region 2 and in Regions 1 and 3, a limit would have to be adopted for PFD reaching those areas. Situation similar to Column 2.

TABLE 2 (contd)

4. B-S → Broadcasting	5. Broadcasting → B-S
	
Interference possible in Regions 1, 2, and 3. Treated in CCIR Report 631. Possible solution: Protect broadcast receivers to a certain level by establishing a PFD for B-S in areas, and on those frequencies within the band where Administrations decide to have terrestrial broadcasting (see Figure 1).	Interference possible in Regions 1, 2, and 3. Treated in CCIR Report 631. Possible solution: Bar terrestrial broadcasting from certain portions of the band, if possible. Keep B-S receivers at the necessary distance from broadcasting stations in the remaining portions of the band (see Figures 3 and 4).
6. F-S → Broadcasting	7. Broadcasting → F-S
	
Interference possible in Regions 1, 2, and 3. <u>Not</u> treated in CCIR Reports. Less severe than Case 4 by virtue of difference in satellite EIRP. Typically, F-S EIRP = 42 dBW (B-S filing to the FCC). B-S EIRP = 63 dBW (CCIR Report 215). Difference = 21 dBw.	Interference possible only in Region 2. <u>Not</u> treated in CCIR Reports. Less severe than Case 5 by virtue of greater antenna directivity at F-S earth station. Typically, a 5-m-diameter dish with first side-lobe down 25 dB (B-S filing to the FCC). At minimum elevation angle of 16 degrees, maximum gain in the horizontal plane will be 1.9 dB (B-S filing). Possible solution: Site F-S earth station on a case-by-case basis, taking advantage of terrain shielding and interference cancellers.

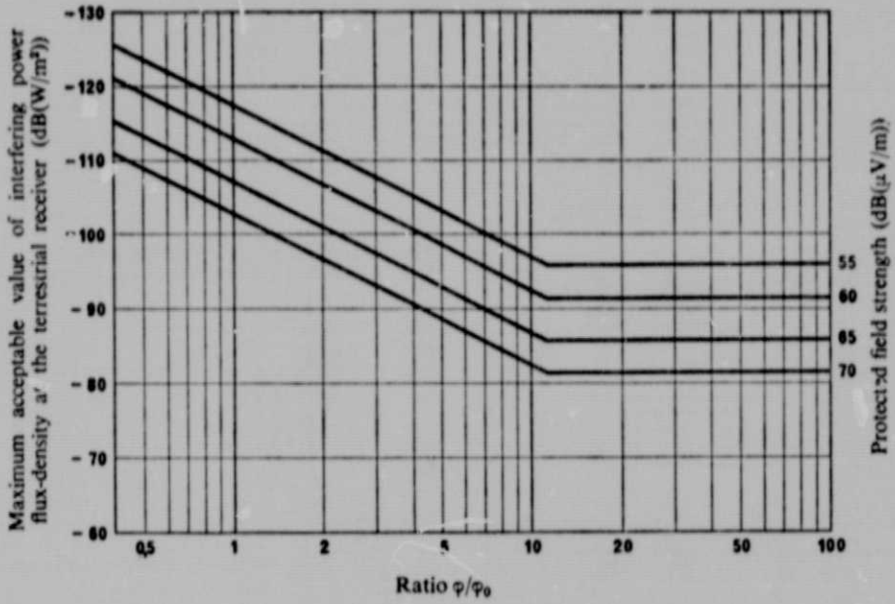


FIGURE 1

Example of maximum acceptable interfering power flux-density at a terrestrial frequency-modulation television broadcast receiver for various protected field strengths

Where:

φ : Angle of discrimination at terrestrial receiver
φ_0: Antenna, 3 dB beamwidth
Protection ratio: 36 dB
f: 12 GHz
Main beam gain, terrestrial antenna: 35 dB (0·6 m)
Terrestrial antenna discrimination: $9 + 20 \log (\varphi/\varphi_0)$

Note. — A value for φ_0 of 2·9° is proposed in Report 215-3 for a 12 GHz terrestrial broadcast receiver.

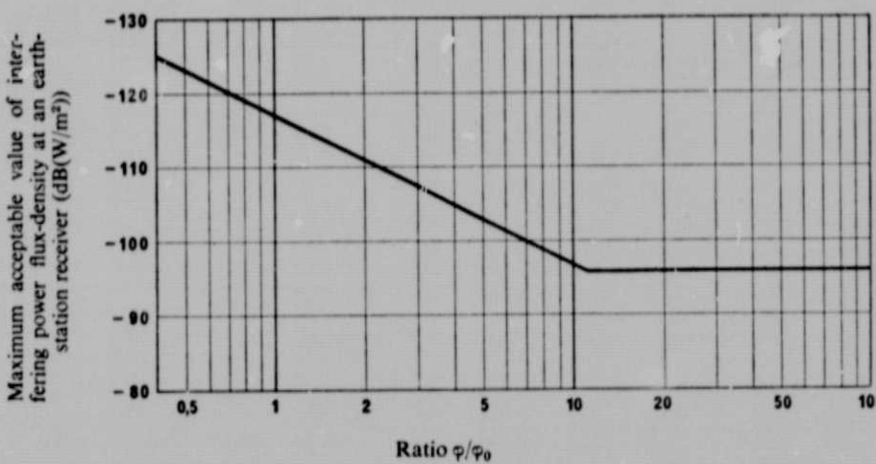


FIGURE 2

Example of maximum acceptable interfering power flux-density at an earth-station receiver (individual reception)

Where:

φ : Angle of discrimination at earth-station receiver
φ_0: Antenna, 3 dB beamwidth
Earth-station antenna off-beam gain: $28 - 20 \log (\varphi/\varphi_0)$
f: 12 GHz

Note. — A value for φ_0 of 2·4° is proposed in Report 215-3 for a 12 GHz satellite broadcasting receiver for individual reception.

Note: Figures 1 and 2 are Figures 4 and 5, respectively, of Report 631, C.C.I.R. XIIIth Plenary Assembly, Volume XI, Geneva, 1975.

ERRATA

Figure 4 and its caption should appear on page 26. The footnote on this page refers to Figure 3.

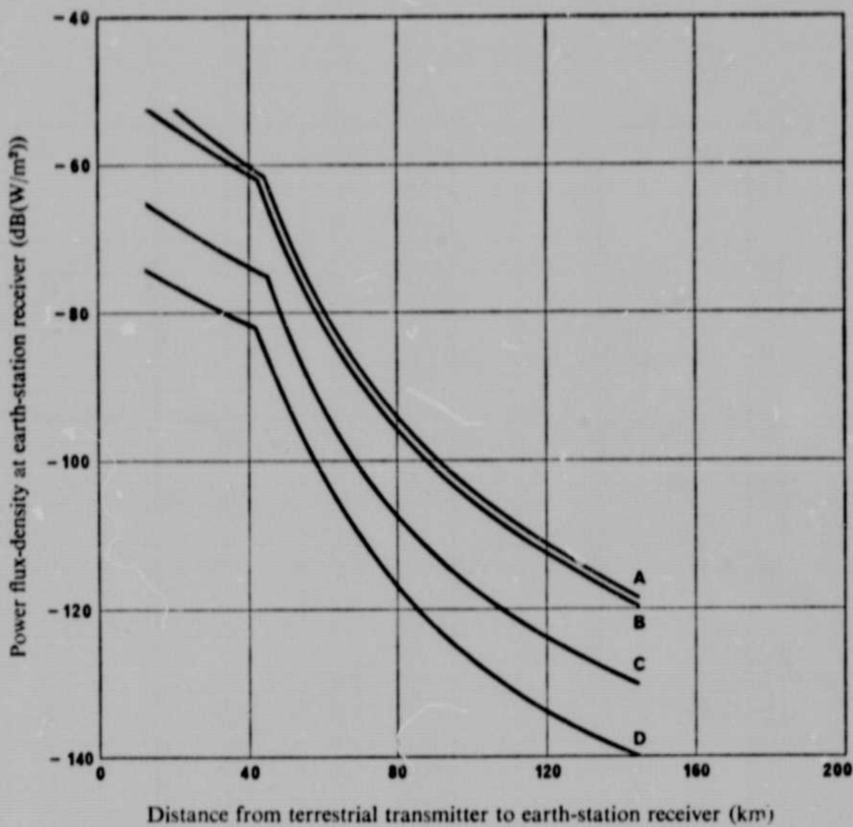


FIGURE 4*

Separation distance to protect earth station receivers from terrestrial transmitters (Japan)

Power flux-density produced by:

A: Studio transmitter link (44 dBW)

B: Amplitude-modulation television broadcasting (43 dBW)

C: Outside broadcast transmitter (28 dBW)

D: Frequency-modulation television terrestrial broadcasting (21 dBW)

*Figure 6 of Report 631, C.C.I.R. XIIIth Plenary Assembly, Volume XI, Geneva, 1975.

ERRATA

Figure 3 and its caption should appear on page 25. The footnote on this page refers to Figure 4.

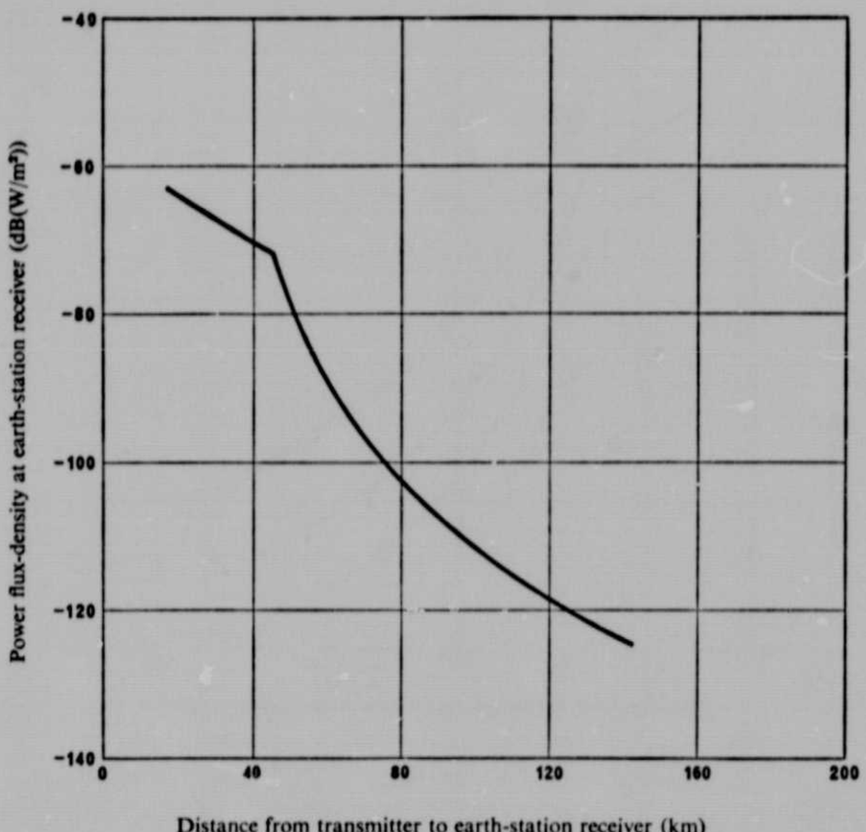


FIGURE 3*

Required separation distance to protect an earth station receiver from an outside-broadcast transmitter (e.i.r.p.: 34 dBW) in the United Kingdom

*Figure 7 of Report 631, C.C.I.R. XIIIth Plenary Assembly, Volume XI, Geneva, 1975.

harm in the U.S. and Canada because only the Mobile Service is in the band in the U.S., and it is on a secondary basis. Neither service is included in the Canadian domestic allocation table.

Interference to earth station receivers in the B-S from F&M transmitters could be harmful if the interfering transmitter is within approximately 300 km. Thus, the only significant sources of interference to U.S. receivers would be, in order of importance, from stations located in Mexico, Cuba, the Bahamas, and Siberia.

To limit this interference, several solutions are possible:

(1) Have the international Table of Allocations amended at some future Conference (1979 would be the first opportunity) to delete F&M from the Table in all regions.

(2) Have the Table amended to make them secondary in Region 2.

(3) Have Mexico delete these services or make them secondary in their domestic table. (Interference from Cuban stations to Florida, and Siberian stations to Alaska can almost be disregarded as possibilities.)

(4) Reach an agreement with Mexico that no F&M stations will transmit from any location with such power and direction as to generate a power flux density at the border greater than some agreed value.

If solution 4 is adopted, a PFD on the order of -100 dBW/m^2 is a reasonable value. This level is taken from CCIR Report 631, assuming the minimum elevation angle of a 0.6-m-diameter earth station antenna as 20 degrees.

Column 2 of Table 2 treats interference from the B-S to the F&M. The only interfering path is from the B-S transmitters to the F&M receivers. If the services are to share, a PFD would be indicated. In the U.S. and Canada, there being no primary sharing with F&M, no PFD limit is necessary. A PFD limit would be necessary in any country of Region 2, or in other regions

intending to use the band for F&M. Initially, the limit should be set as high as possible to permit using earth stations with the lowest possible G/T, should that prove desirable. Studies and subsequent system development may dictate a lower optimum EIRP (and, hence, a lower PFD limit) to achieve better utilization of the geostationary orbit by both B-S and F-S.

Report 215 shows a level of about -100 dBW/m^2 as the necessary flux for individual reception in the 12-GHz band. A PFD on this order might represent a minimum objective.

Column 3 of Table 2 treats interference from the F-S to the F&M. The path is from F-S transmitters to terrestrial receivers of the F&M. This path is now adequately controlled in bands other than the 12-GHz band by Regulations 470N-470NZ, which establish PFD limits.

Insofar as the 12-GHz band is concerned, the situation is the same as in Column 2 of Table 2, dealing with interference from B-S to F&M. Any PFD limit adopted there would be adequate to permit operation of the F-S systems.

B. Sharing Between Satellite and Broadcasting Services

The interference paths to be considered here will be those between the Fixed- and Broadcasting-Satellite Services on one hand and the Terrestrial Broadcasting Service on the other.

Column 4 of Table 2 treats possible interference from the Broadcasting-Satellite Service to the Broadcasting Service.

The preferred solution would be to assume that the angle of discrimination between the terrestrial receiver and the broadcasting satellite will never be less than some value (say, $\phi/\phi_0 > 10$, as defined in Figure 1) and that terrestrial service will be afforded a certain level of protection (say, down to 70 dB/μV/m), and to set the PFD accordingly (about -82 dBW/m^2, from Figure 1).

This limit would have to be observed in those areas and on those frequencies within the band 11.7-12.2 GHz where Administrations desire to implement the Terrestrial Broadcasting Service, as they would be permitted to do under the current Radio Regulations.

Column 5 treats interference from terrestrial TV broadcast transmitters to earth stations receiving from Broadcasting Satellites.

If possible, certain channels within the band should not be used by Terrestrial Services. This reservation of at least a few channels would permit use by the Broadcasting-Satellite Service in a given area and would be the space-age equivalent of the "clear-channel" concept that is in widespread use in the United States, and perhaps in other Administrations, in the medium-frequency (MF) AM broadcast band. Making only one assignment in a large area of the country to a high-power broadcast station prevented the interference that would occur due to the wide night-time range of MF stations. This concept made clear AM reception possible in rural areas far from a local transmitter. The less efficient use of such frequencies was justified on the theory that it was in the public interest for all the people of the U.S. to be served by at least one interference-free AM broadcast station. The barring of Terrestrial Services from one or more channels for satellite use is the equivalent. In urban areas, where the chance of interference from a terrestrial TV station or fixed station would be highest, provision should be made for the reception of a few (or at least one) satellite channels. On other frequencies, receiving installations would have to be located at a distance sufficiently far from terrestrial transmitters to provide acceptable viewing.

Column 6 treats possible interference from Fixed Satellites to TV broadcast receivers. Any solution for Case 2 will also provide the protection necessary in this case because of the lesser EIRP of Fixed Satellites (42 dBw for the proposed B-S system, compared with 63 dBW for a typical Broadcasting-Satellite system, as shown in the system examples in CCIR Report 215).

Case 7 treats possible interference from terrestrial TV broadcast transmitters to Fixed-Satellite earth stations. This case is similar to Case 6 but less severe because of the better antenna directivity to be expected. Terrain and artificial shielding can be used for this more expensive installation to permit them to operate (at their own risk) in the vicinity of terrestrial TV transmitters. Interference cancellers, although expensive, could be justified to permit separations less than would otherwise be possible.

IV. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

A. Summary of Section II.

In summary of the analyses and considerations discussed in Section II of this report, Table 3 is presented. Each of the candidate areas for sharing criteria and performance standards is listed and the conclusion drawn is summarized.

TABLE 3

SUMMARY OF RESULTS

Candidate Sharing Criteria	Page Numbers	Summary
Communication System		
Polarization	5	Use of orthogonal polarization recommended. Further study and experimentation necessary to define preferred techniques and standards.
Channelization	6	No standard recommended at this time.
Quality of communications	7	CCIR recommendations exist. Further study indicated to determine whether amendment or additions are necessary.
Energy dispersal	8	No standard recommended. Acceptable levels of interference and/or power flux density limits are preferred.
Modulation methods	9	No standard should be adopted. Acceptable levels of interference and/or power flux density limits are preferred.
Acceptable levels of interference	10	A basic sharing criterion. Further study required to recommend standard.
Space Station		
Satellite spacing	See WG-B Report	A basic sharing criterion. Further study required to recommend standard.
Stationkeeping	10	±0.1 degree limit recommended for East-West control. For North-South control, no limit is specified; however, ±0.1 degree or the equivalent is suggested.

TABLE 3 (contd)

Candidate Sharing Criteria	Page Numbers	Summary
Satellite repositioning	12	Capability to reposition recommended. However, limit maximum required excursion to ±10 degrees and keep number of moves to a minimum.
Out-of-band emission limits	13	No recommendation at this time. A recommended limit to or from systems in the 11.7-12.2 GHz band will be based on studies now in progress.
Cessation of emissions	14	Capability to command cessation recommended.
Power flux density limits	15	A basic sharing criterion. Not recommended at this time. However, a limit will likely be required in the future.
Antenna pointing accuracy and antenna patterns	16	No value recommended at this time. Control of antenna sidelobes or PFD limits outside service area may be preferable.
<u>Earth Station</u>		
Receiver interference rejection	17	No standard recommended at this time for receiver selectivity. When limits are set for out-of-band emission by transmitters, a complementary limit should be established for receiver selectivity.
Antenna size and discrimination	17	No limit on size recommended at this time. Reasonable sidelobe control is suggested.
Receiver noise temperature	18	No standard recommended. PFD limit is preferred. Low-noise systems should be protected from interference.
Antenna repointing and receiver retuning	19	Capability is recommended; however, number of changes should be minimized.
Antenna pointing accuracy	20	No standard recommended.

B. Conclusion

The values for many candidate sharing parameters have not been specified (and those that have are preliminary) because of uncertainties in system definitions, the services to be offered, and system characteristics.

As a result of the studies and efforts that are described in this report, the following conclusion has been drawn:

> Many system parameters should not be controlled or regulated because control of more fundamental parameters will achieve the desired goal of sharing and efficient use of orbit and spectrum. These fundamental and interrelated parameters include power flux density limits, satellite spacing, and acceptable levels of interference.

C. Recommendations

The adoption of sharing criteria and performance standards involves a complex situation where technical characteristics are interrelated with system costs and require comprehensive analysis to determine the impact on system performance, cost to implement, and improvement to be gained. The current state of knowledge concerning the technical characteristics of domestic communications satellite systems which may share the 11.7-12.2 GHz band, particularly in the Broadcasting-Satellite Service, is deficient from the point of view of making specific recommendations for performance standards. In fact, definitive interpretation of the basic nature of the services to be provided in the two service areas is lacking. With this in mind, the following recommendations are set forth:

(1) Unambiguous interpretations of the definitions of both the Fixed-Satellite and Broadcasting-Satellite Service should be developed. These interpretations should relate to the characteristics of the Services to be provided in addition to postulated system characteristics and their associated technical parameters.

(2) Comprehensive models of the technical characteristics of both Fixed-Satellite and Broadcasting-Satellite systems should be developed.

(3) Detailed studies of candidate performance standards should be conducted accordingly for system cost effectiveness and orbit/spectrum utilization.

(4) A procedure should be instituted to accommodate regional inputs to the study and planning function.

Adoption of specific performance standards should be preceded by the implementation and completion of the studies and definitions recommended above.

APPENDIX A

ANALYSIS OF OUT-OF-BAND EMISSIONS

To gain an estimate of the order of magnitude of the interference problem, the following analysis is presented. Consider the interference created by a satellite operating in the 11.7-12.2 GHz band to a mobile service operating in the band immediately below 11.7 GHz. Five types of satellite systems will be considered, the characteristics of four to be derived from the first. The five types of satellite systems to be considered are:

Type 1	Fixed-Service	Wideband Digital
Type 2	Fixed-Service	Narrowband Digital
Type 3	Fixed-Service	Second Generation
Type 4	Broadcasting-Service	EIRP = 55 dBw
Type 5	Broadcasting-Service	EIRP = 65 dBw

The out-of-band interference caused by a Type 1 satellite system can be estimated from

$$I_{PEAK} = EIRP_{MAX} + PAV - SL - SFS - BWR - ESTFE - FPS \tag{1}$$

where

I_{PEAK} = peak value of out-of-band interference for a satellite operating in the 11.7-12.2 GHz band [dB(W/m^2/4kHz)]

$EIRP_{MAX}$ = maximum value of EIRP (dBW)

PAV = peak-to-average signal level (dB)

SL = spreading loss (dB)

SFS = satellite filter suppression near the band edge (dB)

BWR = conversion factor from transmitted signal bandwidth to 4 kHz, equal to 10 log (BW/4000) (dB)

BW = signal bandwidth (Hz)

ESTFE = earth station transmission filter suppression near band edge (dB)

FPS = peak value of first out-of-band sidelobe (dB)

Using the conversative parameter values presented in Table A-1, the interference is given by

$$I_{PEAK} = EIRP_{MAX} - 10 \log \frac{SBW}{4000} - 181 \tag{2}$$

where SBW is the satellite bandwidth.

For a representative value of EIRP = 45 dBW for a Type 1 Fixed Service and an effective signal bandwidth of 30 MHz, the peak interference is given by

$$I_{PEAK} = 45 - 10 \log \frac{30 \times 10^6}{4 \times 10^3} - 181 \tag{3}$$

$$= -175 \text{ dB}(\text{W/m}^2/4 \text{ kHz})$$

With reference to Radio Regulation No. 470NQ, the power flux density at the earth surface produced by emissions from a space station in the band 8.025-11.7 GHz is given by

$$I(\text{in-band})_{MAX} = -150 \text{ dB}(\text{W/m}^2/4 \text{ kHz}) \tag{4}$$

for angles of arrival δ between 0 and 5 degrees,

$$I(\text{in-band})_{MAX} = 150 + \frac{\delta - 5}{2} \text{ dB}(\text{W/m}^2/4 \text{ kHz}) \tag{5}$$

for angles of arrival δ between 5 and 25 degrees,

$$I(\text{in-band})_{MAX} = -140 \text{ dB}(\text{W/m}^2/4 \text{ kHz}) \tag{6}$$

for angles of arrival between 25 and 90 degrees.

TABLE A-1

ESTIMATE OF OUT-OF-BAND INTERFERENCE

FROM A FIXED-SERVICE SATELLITE

Parameter	Value
Spreading loss	-163 dB
Satellite filter	-5 dB
Bandwidth reduction(1)	$-10 \log \frac{SBW}{4\ kHz}$
Peak-to-average level	+3 dB
First out-of-band peak sidelobe(2)	-13 dB
Earth station transmission filter effect(3)	-3 dB

(1) For a digital bit rate (B.R.) using quadriphase-shift-keying (QPSK) modulation, the effective signal bandwidth is approximately B.R./2 × 1.2.

(2) For a wideband digital signal.

(3) The net effect of the earth station filter and the "reconstitution" by the nonlinear satellite transponder.

Restricting the interference due to satellite operation in the 11.7-12.2 GHz band to 10 dB less than the interference allowed for satellites operating in the band below 11.7 GHz, the $I(\text{allowable})_{PEAK}$ = -155 dB(W/m^2/4 kHz) for a minimum angle of arrival of 15 degrees.

The margin for the Type 1 service is then 20 dB.

Assuming that the Type 2 service causes the same order-of-magnitude of interference out-of-band, the margin is again 20 dB. Assuming a 10-dB increase in EIRP for a second-generation Fixed-Satellite Service (Type 3), the margin is reduced by 10 dB.

For a Broadcasting-Satellite Service (Type 4) with an $EIRP_{MAX}$ of 55 dBW, the margin is approximately 10 dB.

Finally, for a Broadcasting Service (Type 5) with an $EIRP_{MAX}$ of 65 dBW, the margin is reduced to zero.

In conclusion, two points should be noted: (1) out-of-band interference will generally be less than the peak value derived above and (2) for the worst case presented, a Broadcasting Service with an EIRP of 65 dBW, digital transmission was assumed. If the more likely FM modulation is used, approximately 10-dB improvement in the out-of-band emission is estimated when compared to a wideband digital modulation approach.

APPENDIX B

MEMBERSHIP LIST

WORKING GROUP C (SHARING CRITERIA)

JOINT INDUSTRY/GOVERNMENT COMMITTEE FOR 11.7-12.2 GHz

Mr. Jerome D. Barnla
Satellite Business Systems
1750 "K" Street, N.W.
Washington, D.C. 20006
202-466-2660

Mr. George W. Bartlett
Vice President for Engineering
National Association of Broadcasters
1771 "N" Street, N.W.
Washington, D.C. 20036
202-293-3558

Mr. Jeffrey Binckes
DCA/DCEC, Code R410
1860 Wiehle Ave.
Reston, VA 22090
703-437-2454

Mr. Charles H. Breig
Broadcast Bureau
Federal Communications Commission
1919 "M" Street, N.W., Rm. 306
Washington, D.C. 20554
202-632-6495

Mr. William Brook
RCA Global Communications, Inc.
P.O. Box 2244
Princeton, N.J. 08540
609-799-3030

Mr. Samuel A. Brunstein
Mail Sta. 114-B13
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91103
213-354-6219

Mr. J.R. Burke
Joint Council on Educational
Telecommunications
1126 16th Street, N.W.
Washington, D.C. 20036
202-659-9741

Mr. Donald Draper Campbell
Office of Chief Engineer
Federal Communications Commission
2025 "M" Street, N.W., Rm. 7102
Washington, D.C. 20554
202-632-7073

Mr. Raymond B. Crowell
Common Carrier Bureau
Federal Communications Commission
1919 "M" Street, N.W., Rm. 502
Washington, D.C. 20554
202-632-7265

Mr. C. Louis Cuccia
Principal Engineer, Code G-93
Western Development Labs
Aeronutronic Ford Corporation
3939 Fabian Way
Palo Alto, CA 94303
415-494-7400, Ext. 4243

Mr. Allen Das
Office of the Chief Engineer
Federal Communications Commission
2025 "M" Street, N.W., Rm. 7128
Washington, D.C. 20554
202-632-7040

Mr. Edwin W. Davis
Staff Consultant-Network Transmission
CTN Eng & Devel Dept - 30th Fl.
CBS Inc.
51 W. 52 Street
New York, NY 10019
212-975-3793

Mr. Patrick C. Dougherty
Hughes Aircraft Co.
Bldg. 373, Rm. 9110
P.O. Box 92919, Airport Station
Los Angeles, CA 90009
213-648-4937

Mr. E. L. Eaton, Code TN
National Aeronautics and Space Administration
600 Independence Ave, S.W.
Washington, D.C. 20546
202-755-2480

Mr. A. James Ebel
Network Affiliates Assn.
KOLN-TV
40th and W Streets
Lincoln, NE 68503
402-467-4321, Ext. 211

Mr. GianPiero Forcina
Mail Sta. 56-762
Comsat General Corporation
950 L'Enfant Plaza, S.W.
Washington, D.C. 20024
202-554-6876

Mr. Samuel W. Fordyce
National Aeronautics & Space Administration
600 Independence Ave., S.W.
Washington, D.C. 20546
202-755-8565

Mr. O.C. Foster
AT&T
295 North Maple Ave.
Basking Ridge, NJ 07920
201-221-4966

Mr. Jerry Freibaum
Code ECE, Office of Applications
National Aeronautics & Space Administration
600 Independence Ave., S.W.
Washington, D.C. 20546
202-755-8570

Mr. Thomas M. Gluyas
RCA Commercial Communications Division, Broadcast Systems
P.O. Box 7
Gibbsboro, NJ 08026
609-963-8000 PC 3602

Mr. Richard G. Gould
Satellite Systems Engineering, Inc.
7315 Wisconsin Ave.
Washington, D.C. 20014
301-652-4660

Mr. George W. Haydon
Department of Commerce
Office of Telecommunications
Boulder, CO 80302
303-499-1000, Ext. 3583

Dr. Albert Horley
Communication Satellite Planning Center
701 Welch Rd., Suite 225
Palo Alto, CA 94304
415-497-4521

Mr. Howard H. Hupe
Dept. of Health, Educ. & Welfare
Rm. 5518A, North Building
330 Independence Avenue, S.W.
Washington, D.C. 20201
202-245-1891

Mr. Edward R. Jacobs
Office of the Chief Engineer
Federal Communications Commission
2025 M. St., NW, Rm 7302
Washington, D.C. 20554
202-632-7067

Dr. James Janky
Communication Satellite Planning Center
701 Welch Rd., Suite 225
Palo Alto, CA 94304
415-497-4521

Mr. Donald Jansky
Office of Telecommunications Policy
Executive Office of the President
1800 "G" Street, N.W.
Washington, D.C. 20504
202-395-4876

Dr. Michael Jeruchim
Room 20C29
General Electric Company
P. O. Box 8555
Philadelphia, PA 19101
215-962-4792

Mr. Harold L. Kassens
A.D. Ring and Associates
1771 "N" Street, N.W., Suite 420
Washington, D.C. 20036
202-296-2315

Mr. Sidney Kessler
USIA
25 "M" Street, S.W.
Washington, D.C. 20547
202-755-5047, Ext. 5504

Mr. George Knouse, Code ECE
National Aeronautics and Space Administration
600 Independence Ave., SW
Washington, D.C. 20546
202-755-8571

Mr. Ronald J. Lepkowski
Federal Communications Commission
Common Carrier Bureau
1919 "M" Street, N.W.
Washington, D.C. 20554
202-632-5930

Mr. Neal K. McNaughten
Asst. Chief, Broadcast Bureau
Federal Communications Commission
1919 "M" Street, N.W., Rm. 314
Washington, D.C. 20554
202-632-6460

Mr. Martin H. Meaney
Manager of Allocations Eng.
National Broadcasting Company, Inc.
30 Rockefeller Plaza, Rm. 1240-W
New York, NY 10020
212-247-8300, Ext. 3354

Mr. Edward F. Miller
Mail Sta. 54-5
NASA Lewis Research Center
21000 Brookpark Rd.
Cleveland, OH 44135
216-433-4000, Ext. 6892

Mr. John E. Miller
Code 951
NASA Goddard Space Flight Center
Greenbelt, MD 20771
301-982-5885

Mr. Greg Nichols
Public Service Satellite Consortium
2480 West 26th Ave.
Denver, CO. 80211
303-458-8000

Mr. Gerald W. Olmsted
Coastcom
2346 Stanwell Dr.
Concord, CA 94520
415-825-7500

Mr. Harry Olsson
General Attorney
CBS Inc.
51 West 52nd St.
New York, NY 10019
212-975-4035

Mr. Pierre A. Portmann
10224 Farnham Dr.
Bethesda, MD 20014

Dr. James Potter
Federation of Rocky Mountain States
Suite 300B
2480 West 26th Avenue
Denver, CO 80211
303-458-8000

Mr. James Potts
Mail Sta. 52-141
COMSAT
950 L'Enfant Plaza, S.W.
Washington, D.C. 20024
202-554-6270

Mr. Richard O. Pullen
General Attorney
Federal Communications Commission
1919 "M" Street, N.W., Rm. 538
Washington, D.C. 20554
202-632-6440

Mr. Jayaram Ramasastry
Western Union Telegraph Co.
1 Lake Street
Upper Saddle River, NJ 07458
201-825-5111

Mr. Sankaran Ramji
Hughes Aircraft Co.
909 Sepulveda Blvd.
El Segundo, Los Angeles, CA 90009
213-648-2944

Mr. Edward E. Reinhart
Mail Sta. 114-B13
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91103
213-354-6929

Mr. Philip Rice
MCI Telecommunications
1150 - 17th St., N.W.
Washington, D.C. 20036
202-872-1600

Mr. Philip A. Rubin
Director of Engineering Research
Corporation for Public Broadcasting
1111 16th Street, N.W.
Washington, D.C. 20036
202-293-6160

Mr. Peter Sawitz
Operations Research, Inc.
1410 Spring Street
Silver Spring, MD 20910
301-588-6180

Dr. Kalmann Schaefer
Executive Office of the President
Office of Telecommunications Policy
Washington, D.C. 20504
202-395-3782

Mr. John Serafin
American Broadcasting Co., Inc.
57 West 66th Street
New York, N.Y. 10023
212-581-7777, Ext. 7169

Dr. Michael J. Sites
Stanford Electronics Lab
Rm. 225, Durand Bldg.
Stanford, CA 94305
415-497-3595

Mr. Carl E. Smith
8200 Snowville Road
Cleveland, OH 44141
216-526-4386

Dr. Ernest K. Smith
Department of Commerce
Office of Telecommunications
Boulder, CO 80302
303-499-1000, Ext. 3177

Ms. Carol Vance
Pierson, Ball and Dowd
1200 - 18th St., N.W.
Washington, D.C. 20036
202-331-8566

Mr. Robert M. Walp
Office of Telecommunication
Pouch AC
Juneau, AK 99811
907-465-3550

Mr. H. E. Weppler
AT&T
295 North Maple Ave.
Basking Ridge, NJ 07920
201-221-4960

Mr. John L. Wibbe
Computer Sciences Corp.
6565 Arlington Blvd.
Falls Church, VA 22046
703-533-8877

Mr. Edmund A. Williams
Public Broadcasting Service
475 L'Enfant Plaza, S.W.
Washington, D.C. 20024
202-488-5188

Mr. David L. Wright
Mail Sta. 49-3
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135
216-433-4000, Ext. 6816

Mr. Leland B. Zahalka
GTE
One Stamford Forum
Stamford, CT 06904
203-357-2659